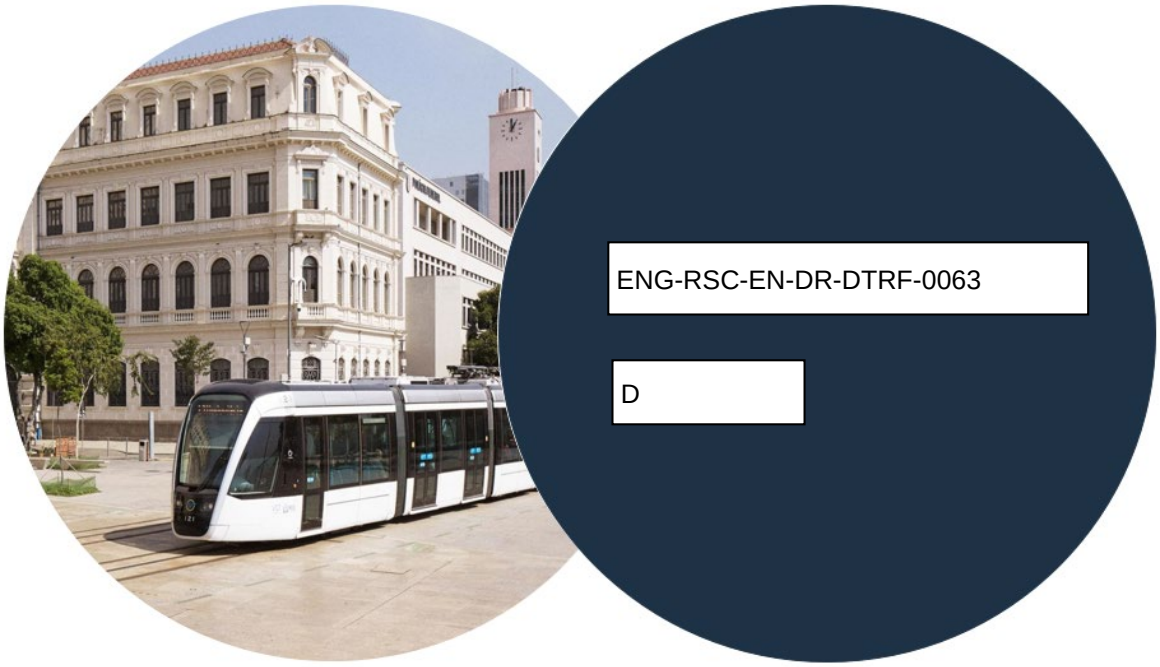

ENG-RSC-EN-DR-DTRF-0063

D

DTRF_150266-1-
Additive Manufacturing-
Purchase of Metallic Parts

DOCUMENT SUMMARY :

Previous reference ENG-RSC-EN-DR-STD-0063

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ALSTOM STANDARD
DTRF 150266-1 REV D

ALSTOM STANDARD FOR RAILWAY APPLICATIONS
ADDITIVE MANUFACTURING – PURCHASE OF METALLIC PARTS

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TABLE OF MODIFICATIONS

Revision	Publication	Summary of Changes
D	24/01/2022	Adjustment of steel values after tests campaign
C	10/05/2021	Steel added
B	24/01/2020	Review and proposals with SNCF and SQD team
A1	31/01/2019	Global review prior to publication
A	16/01/2019	Creation

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CONTENTS

1. Purpose 5
2. Normative references 6
   2.1. Standard references 6
   2.2. ALSTOM Standard references 6
3. Terms and definition 7
   3.1. Terms 7
   3.2. Criticality level 8
   3.3. Control class definition 9
   3.4. Flexibility 9
   3.5. Traceability 10
   3.6. Materials designation 10
4. Requirements 11
   4.1. General 11
   4.2. Part ordering information 11
      4.2.1 Marking 11
      4.2.2 Packaging and surface protection 12
         4.2.2.1 Storage conditions 12
         4.2.2.2 Packaging 12
   4.3. Part definition 12
      4.3.1 Part geometry 12
      4.3.2 Tolerances 13
      4.3.3 Surface texture 13
      4.3.4 Part manufacturing process 14
      4.3.5 Manufactured part feedstock 15
      4.3.6 Finishing 15
         4.3.6.1 Finishing by material removal 16
         4.3.6.2 Finishing by bonding or welding 16
      4.3.7 Acceptable imperfections or non-conformities 17
   4.4. Part characteristics, functionality and performance 18
      4.4.1 Part characteristics 18

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4.4.2 Post-processing 19
4.4.3 Parts 19
5. Appendices 20
5.1. Appendix 1: AM process principles (ISO 52900) 20
5.2. Appendix 2: Sample definition (ISO/ASTM 52921) 21
5.2.1 Cartesian coordinate system 21
5.2.2 Right hand rule for positive rotations 21
5.2.3 Orthogonal orientation notation 22
5.2.3.1 Bilateral symmetry 23
5.2.3.2 Abbreviation of orthogonal orientation notation 23

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1. PURPOSE

This ALSTOM Standard defines and specifies requirements for purchased parts made by additive manufacturing (AM) for Interior and semi-structural parts.

This ALSTOM Standard is based upon standard ISO/ATSM 52901 and specifies for each section:

- ALSTOM position (as buyer), in case of several options in standard
- Additional requirements stated by ALSTOM.

Any potential deviation from the prescriptions laid down in this ALSTOM Standard should be:

- Clearly written in Clause-by-Clause document
- Agreed by ALSTOM and Supplier

Without any complementary information on the definition plan or in purchase specification, the product shall be compliant with requirements by default given in this ALSTOM Standard.

Even if International Standards exist in different languages, English version is considered as official reference.

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2. NORMATIVE REFERENCES

2.1. STANDARD REFERENCES

Reference	Title
ISO 286-2	Geometrical product specifications (GPS) - ISO code system for tolerances on linear sizes - Part 2: Tables of standard tolerance classes and limit deviations for holes and shafts
ISO 2768-1 / 2	General tolerances – Part 1: Tolerances for linear and angular dimensions without individual tolerance indications / Part 2: Geometrical tolerances for features without individual tolerance indications
ISO 15708	Non Destructive Testing – Radiation Methods – Computed Tomography
ISO 17296-2 / 3	Additive manufacturing — General principles — properties – Part 2: Overview of process categories and feedstock / Part 3: Main characteristics and corresponding test methods
ISO/ASTM 52900	Additive Manufacturing — General principles – Terminology
ISO/ASTM 52901	Additive Manufacturing — General principles – Requirements for Purchased AM Parts
ISO/ASTM 52915	Standard Specification for Additive Manufacturing File Format (AMF) Version 1.2
ISO/ASTM 52921	Additive Manufacturing — Standard Terminology for Additive Manufacturing - Coordinate Systems and Test Methodologies
EN 10204	Metallic Products – Types of Inspection Documents
EN 15085	Railway Applications – Welding of Railway Vehicles and Components
EN 61675	Radionuclide imaging devices. Characteristics and test conditions. Positron emission tomographs
ASTM E1441	Standard Guide for Computed Tomography (CT) Imaging
ASTM F2924	Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium with Powder Bed Fusion
ASTM F3122	Evaluating Mechanical Properties of Metal Materials Made via Additive Manufacturing Processes
ASTM F3184	Standard Specification for Additive Manufacturing Stainless Steel Alloy (UNS S31603) with Powder Bed Fusion

Any other standard listed in the document but not included into the above table is just for information and is not mandatory.

2.2. ALSTOM STANDARD REFERENCES

Reference	Title
ENG-FRM-001	Supplier Form: Commitment & Declaration on Dangerous Substances
ENG-STD-003	Instructions to Suppliers concerning commercialization and use of dangerous substances

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3. TERMS AND DEFINITION

3.1. TERMS

The main process definitions below are extracted from ISO/ASTM 52900 regarding additive manufacturing and will be used in this ALSTOM Standard.

TERM	DEFINITION
Powder bed fusion	AM process in which thermal energy selectively fuses regions of a powder bed. The thermal energy can be brought by laser or electron beam system (**LBM, DMLS®, SLM®**).
Dangerous substance	Each substance considered as dangerous regarding ENG-FRM-001 and ENG-STD-003.

The main data exchange format definitions below are extracted from ISO/ASTM 52900 regarding additive manufacturing and will be used in this ALSTOM Standard.

TERM	DEFINITION
STEP	Standard for the exchange of product model data.
STL	File format for model data describing the surface geometry of an object as a tessellation of triangles used to communicate 3D geometries to machines in order to build physical **parts**.
AMF	Additive Manufacturing File Format (ISO/ASTM 52915). AMF files are typically exported by computer-aided design (CAD) software, scanning software, or directly from computational geometry algorithms.

The parts definitions below are extracted from ISO/ASTM 52901 regarding manufacturing and will be used in this ALSTOM Standard.

TERM	DEFINITION
Prototype	Physical representation of all or a component of Part that will be tested to validate design, mechanical properties or other properties.
Qualification (Type) part	Part fabricated before the start of production which is used to qualify specific aspects of the manufacturing process or part characteristics in order to use as a basis to initiate production.
First production part	Part with the same geometry (and with the same tolerances), same material and same properties as the one requested by the order that allows verification by ALSTOM that the production processes are capable of producing parts that meet the requirements (First Article Inspection: FAI).
Reference part	Part with characteristics similar to the desired final parts but with different geometry or scale or features that can be easily measured or characterized.

The other following definitions will be used in this ALSTOM Standard.

TERM	DEFINITION

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Pre-serial part	Number of parts controlled as type part in order to validate the quality process. The minimum should be 5 parts from different batches.
Unique part	Part that will be used by customers, suppliers or any other person, to be handled.
Serial part	Part that will be used by customers, suppliers or any other person and produced in series, carried out with same production process flow
Tooling	Part that will be used for easing the manufacturing in ALSTOM plant.
Molding	Part that will be used for creating molds to realize casted parts specified by DTRF 150203 (aluminum), DTRF 150204 (steel) or DTRF 150237 (iron)
Normal area	Normal Area (Area A) on the part which must comply with the mechanical requirements stated in this ALSTOM Standard. The corresponding part area is outside the designated.
Designated area	Designated area (Area B) on the part which must comply with the mechanical requirements stated in this ALSTOM Standard and shall be submitted to dedicated quality inspections. A casted part may NOT be declared as being 100% designated area.

3.2. CRITICALITY LEVEL

The following testing categories define the parts safety level:

- **High (H):** Tests for highly Engineered parts (safety). They are structural parts.
- **Medium (M):** Tests for Functional parts which sustain some loads. However, these parts are not safety critical (semi-structural parts).
- **Low (L):** Tests for Design or Prototype parts.

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3.3. CONTROL CLASS DEFINITION

There are 2 inspection frequencies: N1 and N2. They are defined in the part definition drawing for each area A, B:

- **N1** is an inspection frequency imposed by ALSTOM on **all** parts **(100%).**
- **N2** is an inspection frequency suggested by supplier and validated by ALSTOM. The N2 inspection frequency only applies to serial parts.

The N2 inspection frequency is defined by the supplier for the following inspections:

- Radiographic inspection,
- Dimensional,
- Density,
- Chemical analysis,
- Micrographic analysis,
- Mechanical tests (hardness, tensile, fatigue),
- Tomography inspection,
- Eddy current inspection.

3.4. FLEXIBILITY

Some recommendations are given in chart form and each function is characterized by the limits to be reached. For each of the functions are associated one or several acceptance criteria (requirement requested or required for the implementation of the assembly), as well as the levels (quantification of the criterion on an adapted scale) with a flexibility (tolerance).

Flexibility	Comments
F0	The specified conditions can in no case be put back into question. The requirement must be met.
F1	The requirement is not mandatory but must be followed, unless an alternative solution can be demonstrated to be at least equivalent.

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3.5. TRACEABILITY

The supplier must establish and maintain an identification and traceability system of the products at each stage of the manufacturing, inspection and delivery phases, as well as of the subcontractor's operations and products in order to recap the history of all associated data and to attribute them to the concerned products.

The system must specifically cover the following fields, whatever the safety (criticality) level of the part:

- Origin of the agreed materials and properties per AM batch,
- Manufacturing operations (see §4.3.4), including thermal treatment,
- Samples well positioned and realized on the same batch and same TTh process,
- Recording/archive machine data and process report (inert level, thermal cycle on bed and build chamber, oxygen level and variations, stop/restart process),
- Inspections and tests.

The traceability system must enable the identification of all parts undergoing the same manufacturing or inspection process.

The required test reports must be written according to EN 10204 certificate 3.1.

3.6. MATERIALS DESIGNATION

The following materials are validated by ALSTOM. Any other material must be validated by ALSTOM before using.

Several types of materials can be used for Metal Additive Manufacturing. For each of them, the corresponding process, manufacturing conditions and controls will be adapted and described in the following chapters:

Process category		**Powder Bed Fusion**	
Source of fusion		**Laser**	**Electron beam**
Material	**Grade**	**-**	**-**
Stainless steel ALM-P-316L	US 316L EN 1.4404	X	NA
Titanium ALM-P-TA6V	Ti6Al4V	X	X
Aluminum * ALM-P-AlSM	AlSi10Mg or AlSi7Mg	X	NA
Steel ALM-P-ST	16MnCr5 or E185	X	NA

* Could be considered similar to EN-AC 42000 and 43000 grades according to EN 1706.

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4. REQUIREMENTS

4.1. GENERAL

The elements described in the following sections will be included in the purchase order subject to agreement between ALSTOM and the part supplier. A corresponding Clause by Clause document will be agreed.

4.2. PART ORDERING INFORMATION

4.2.1 MARKING

Utilization Constraints	***Criterion***	***Level***	Area	Flexibility
Position of mandatory or optional information	Position	In marking area defined on the drawing or 3D model	A, B	F0
	Minimum height of characters	4 - 6 mm	A, B	F1
Information	Mandatory	Material designation	A, B	F0
		Supplier logo	A, B	F0
		Traceability item (e.g. batch reference)	A, B	F0
		Identify (model reference or item reference)	A, B	F0
Information	Optional	If optional information must be marked, this must be clearly indicated on the definition or inspection drawing	A, B	F0
		ALSTOM definition drawing reference (DID)	A, B	F1
		ALSTOM definition drawing revision (DID)	A, B	F1
		ALSTOM customer drawing reference	A, B	F1
		Drawing reference or supplier part reference	A, B	F1
		Heat treatment reference	A, B	F1
		Model reference	A, B	F1
		Chronological serial number	A, B	F1
		ALSTOM DI item code of the machined finished part	A, B	F0
If the information is embossed	Tool	Foam-tipped punch to prevent cracks from forming	A, B	F0
If the information is made during AM process	Type	Molding onto the part	A, B	F1
If the part is painted (see drawing or order)	Legibility of the marking	Legible after painting	A, B	F0

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4.2.2 PACKAGING AND SURFACE PROTECTION

4.2.2.1 STORAGE CONDITIONS

When precautions are needed, the supplier shall document and approve the procedures and precautions to be taken for storage of parts, powder and equipment, in this case, at the end of the project.

4.2.2.2 PACKAGING

The parts must be protected:

- Against impact and damage during storage and transport, particularly the machined areas and the future welded areas.
- Against corrosion (aggressive gases/liquids, humidity, rain, water, snow…).

The cleaning and degreasing of certain surfaces will be defined in supply chain specification depending on parts and validated with supplier.

Additionally to supply chain specification, the packaging will be defined to avoid any injuries to people (no sharp edges and no powder remaining) and will contain at least the order, parts and quantity identifications.

4.3. PART DEFINITION

4.3.1 PART GEOMETRY

The part definition shall include the following elements:

- Engineering drawing reference (number, index and version) if applicable,
- Digital file reference (name, format, version) if applicable,
- Geometry description through:
    - Engineering drawing that fully defines the part, or
    - Digital file containing the 3D model or the part geometry information in Step, STL (with units definition) or AMF format.

ALSTOM will deliver 3D model with step format file.

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4.3.2 TOLERANCES

Any indication on drawing will should be consider prior than minimum requirement expressed in the table below.

Semi-finished parts	Criterion	Level	A, B areas
Dimensional tolerances between 2 surfaces by default	ISO 286-1 ISO 286-2	JS13 / js13	Control plan to be validated by Alstom (F1)
Geometrical tolerances from datum system	ISO 286-1 ISO 286-2	IT13	
Machining allowances	ISO 8062-3	RMAG F	
Finished parts	**Criterion**	**Level**	**A, B areas**
Linear dimensional tolerances between 2 surfaces with no individual tolerances	ISO 2768-1	m	Control plan to be validated by Alstom (F0)
Geometrical tolerances from main finished datum system	ISO 8062-3	GCTG 6	Control plan to be validated by Alstom (F1)

4.3.3 SURFACE TEXTURE

The surface texture (also known as surface finish) of the part is specified in the below table after sand blasting.

Utilization Constraints	Criterion	Level	A, B areas	Flexibility
Visual inspection Surface state without machining	As per control plan	Ra: 6,3 Rz: 40*	B N1	F0 F1
		Ra: 12,5 Rz: 60*	A N1	F0 F1
Visual inspection Machined surface state	As per control plan	Ra defined	A, B N1	F0

* These values will be set after type parts manufactured.

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4.3.4 PART MANUFACTURING PROCESS

The build orientation shall follow the rules given in ISO/ASTM 52921. **If any process step from powder preparation to machining is changed, acceptance must be submitted to ALSTOM who will decide whether to run a requalification on type parts or not**.

If access to following data in case of part failure is not possible, the supplier will assume the fully responsibility of the consequences due to this failure.

The following machine characteristics will be archived and remain available during 5 years for expertise:

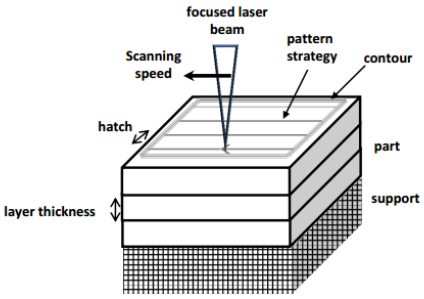
- Designation
- Serial number
- Software release
- Manufacturing parameters references
- Maintenance identification (type, date)
- Print bed leveling & calibration
- Qualification certificate after maintenance.

The following printing parameters will be archived and remain available during 5 years for expertise:

- Supports definition (location, density & geometry)
- Slicing strategy (including tessellation level)
- Temperature follow-up
- Gas (designation, oxygen ratio and level)

The following printing parameters will be detailed in a short document and sent to ALSTOM for information:

- Layer thickness
- Laser: power, scan speed
- Hatch distance
- Print bed material & size
- Number of parts per batch (if the print bed is shared with other customer, ALSTOM must be informed).



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4.3.5 MANUFACTURED PART FEEDSTOCK

The type and/or limits of the chemical composition of the feedstock for the manufactured part shall be compliant with existing standards and/or material specifications. **Any change after FAI will be discussed with ALSTOM to acceptance.**

Utilization Constraints	Criterion	Level	Number	Flexibility
Chemical analysis	Values of components	Compliant with corresponding material standard	1 per test batch at the end of the process N1 for class H N2 for class M	F0 F0 F1
Grains size	Granulometry	D10, D50, D90	1 per powder batch N1 for class H N2 for class M	F0
Grain morphology	Spherical Shape	MEB		F0 F1
Powder re-use	Frequency	10 times max 50 times max	Aluminum, Titanium, Steel Stainless steel	F1
Bed plate	Thickness (mini)	30 mm for alu/steel 40 mm for titanium	-	F0
	Flatness	≤ 30 µm	-	F1

The mix of powder batches could be authorized after ALSTOM validation for:

- Same powder supplier
- Checking of the mix: granulometry, chemical analysis, grains size.

4.3.6 FINISHING

Any repair shall be communicated to ALSTOM and authorized prior to being performed. The authorized repair methods (such as repair by material deposition) and corresponding repair conditions shall be specified if needed and shall be approved by ALSTOM.

The parts will be heat treated according to:

- ASTM F 2924 Class B for Titanium (annealed)
- ASTM F 3184 Class B for Stainless steel (annealed)
- Heat treatment T6 for Aluminum
- Heat treatment QT for Steel.

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4.3.6.1 FINISHING BY MATERIAL REMOVAL

Utilization Constraints	Criterion	Level	Area	Flexibility
Finishing is allowed only if dimensions and surface states indicated in the part definition are respected.	Condition	Sand blasting	A, B	F0
Surface state or reworked area	Roughness	Ra: 6,3 Rz: 40	A, B	F1
Any process with the purpose of masking a defect	Masking of defects	Prohibited	A, B	F0

4.3.6.2 FINISHING BY BONDING OR WELDING

FINISHING BY BONDING
FORBIDDEN (F0)

FINISHING BY WELDING	
AUTHORIZED ACCORDING TO EN 15085 (F1)	
EN 15085 Classification	CRITICAL DEFINITION ADDITIVE MATERIAL
CL1	H
CL2	M
CL3	L

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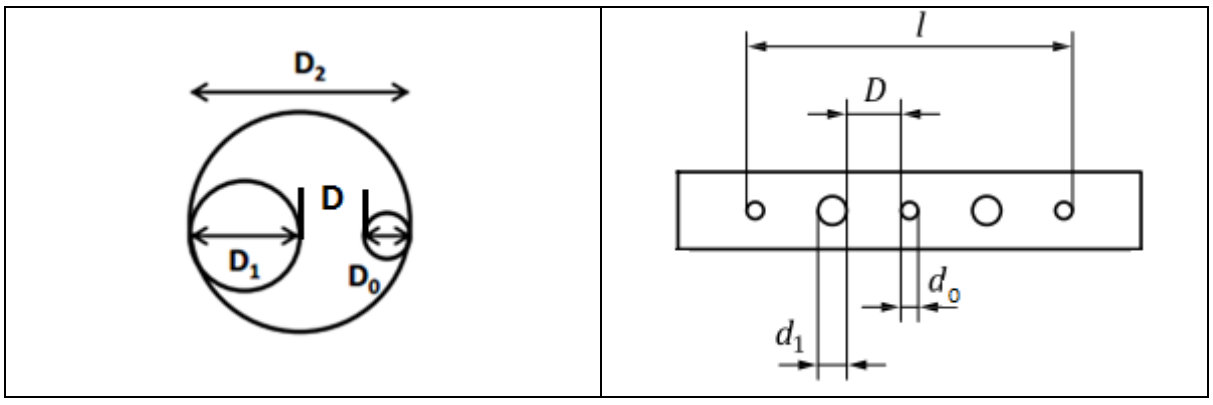
4.3.7 ACCEPTABLE IMPERFECTIONS OR NON-CONFORMITIES

Allowances for cracks, defects, discontinuities, foreign material, inclusions, acceptable imperfection(s) or deviation(s), discolorations, and porosity shall be agreed upon between the part provider and ALSTOM according to the following table (Computed Tomography [CT] or Radiography).

Utilization Constraints	Criterion	Class L	Class M	Class H	Flexibility
Porosity	Maximum level	2,0%	1,5%	1,0%	F1
Observed field size	Image analysis	6 x 5 mm So 30 mm²	2 x 3 mm So 6 mm²	1,4 x 1,4 mm So 2 mm²	F1
Defect size*	Maxi isolated defect (D2)	< 500 µm	< 400 µm	< 300 µm	F1
	Maxi cumulated defect (l)	< 1,5 mm	< 0,9 mm	< 0,6 mm	F1
	Mini measurable (Do)	100 µm	75 µm	50 µm	F1

* When the distance between 2 porosities is lower than the diameter of the biggest one (D < D1), both porosities and the gap between them corresponds to the defect size observed (the two porosities are considered as one; see figure below).

When the distance between 2 porosities is upper than the diameter of the biggest one (D > D1), but more than 3 porosities are aligned in one direction, then the global defect corresponds to a cumulated one (see figure below). However, if D is upper than 5xD1, the porosities will be considered as separated.



The porosity with diameter lower than D0 are not considered.

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4.4. PART CHARACTERISTICS, FUNCTIONALITY AND PERFORMANCE

4.4.1 PART CHARACTERISTICS

Part characteristics, including those found in ISO 17296-3 or ASTM D3122, shall meet the requirements of applicable standards or shall be agreed upon between the part provider and ALSTOM. Part characteristic information shall be included in the quality record for the purchased AM part. A sample geometry definition is given in Appendix 2.

PROCESS CONTROL *(Samples definition)*						
Type	***Criterion***	***Level***	***A, B areas***	***Safety Level***		
				L	***M***	***H***
Control tower	Location	In print bed corner	1 per test batch N1 (F0)	X	X	X
Tests samples	Orientation	X-axis or Y-axis (3 mini along the longest direction of the 3dprinted parts) Z-axis (3 mini)	1 set per test batch N1 (F1)		X	X
Reference sample	Location Thickness	Close to critical area(s) Same as critical area(s)	1 per test batch N1 (F0)		X	X

MECHANICAL PROPERTIES METHODS *(Tests definition)*						
Utilization Constraints	***Criterion***	***Level***	***A, B areas***	***Safety Level***		
				L	***M***	***H***
TENSILE TESTING (all types of sample)	ISO 6892-1	Yield, tensile strength and elongation according tables 1 and 3 and density	N1 - (F0)	X	X	X

MECHANICAL PROPERTIES CHARACTERISTICS *The mechanical properties must be guaranteed throughout the part* *(ensure the correlation between the adjacent sample and the dissection sample)*						
Utilization Constraints	***Minimum Level***	***Material Type***				***Flexibility***
		TiAl6V4	***Stainless steel***	***Aluminum***	**Steel**	
TENSILE TESTS (For each sample.)	**Standard TTH** Tensile strength Yield strength Elongation	**ASTM F2924 class B** 895 MPa 825 MPa 10%	**ASTM F3184 class B** 515 MPa 205 MPa 30%	**-** **T6** 280 MPa 220 MPa 5%	- **QT** 950 MPa 850 MPa 7%	F0

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4.4.2 POST-PROCESSING

Post-processing of as-built parts may be necessary to meet ALSTOM requirements. Post-processing may include:

- Subtractive manufacturing,
- Surface finishing,
- Thermal processing,
- Other operations.

Post-processes shall be performed in accordance with applicable standards or as agreed upon between the part provider and ALSTOM.

4.4.3 PARTS

COMPUTERIZED TOMOGRAPHY CONTROL (Control procedures must be approved by 3 COFREND agents and sent to ALSTOM for validation) (Agents must be qualified according to standard ISO 9712)			
Utilization Constraints	***Criterion***	***Level***	***B areas***
CT examination	ISO 15708-3	§5.5 + Annex A	N1
Image Quality	Voxels	> 9	(F0)
Linear defects	Quantity	0	N1 - (F0)
Defect size*	Maxi isolated defect (D2)	< 300 µm	F1
	Maxi cumulated defect (l)	0,9 mm	F1
	Mini measurable (D0)	50 µm	F1

* When the distance between 2 porosities (D) is lower than the diameter of the biggest one (D1), both porosities and the gap between them corresponds to the defect size observed (the two porosities are considered as one).

When the distance between 2 porosities is upper than the diameter of the biggest one (D > D1), but more than 3 porosities are aligned in one direction, then the global defect corresponds to a cumulated one.

Ultrasonic test:
For areas B, ultrasonic test can be suggested for the series control of internal health of the part to complete or replace the radiographic or CT control. The parameter of this ultrasonic control, standard to be applied, and series frequencies must be approved by ALSTOM, during the FAI.

Penetrant test (PT):
For areas A, penetrant test can be used (< 1 mm indication) for identifying residual cracks and/or support removal issues.

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5. APPENDICES

5.1. APPENDIX 1: AM PROCESS PRINCIPLES (ISO 52900)

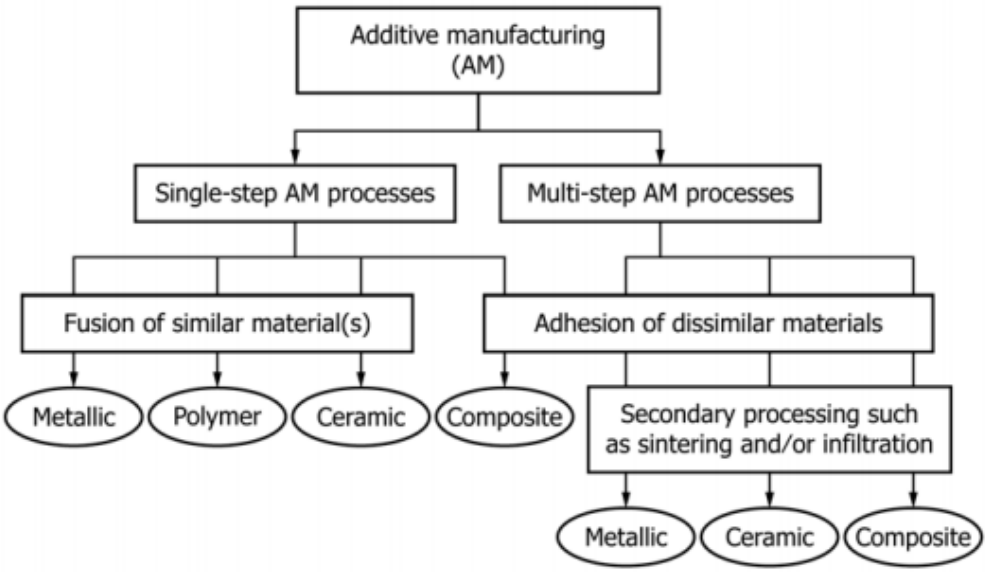

FIG. A1.1 Single-step and Multi-step AM process principles

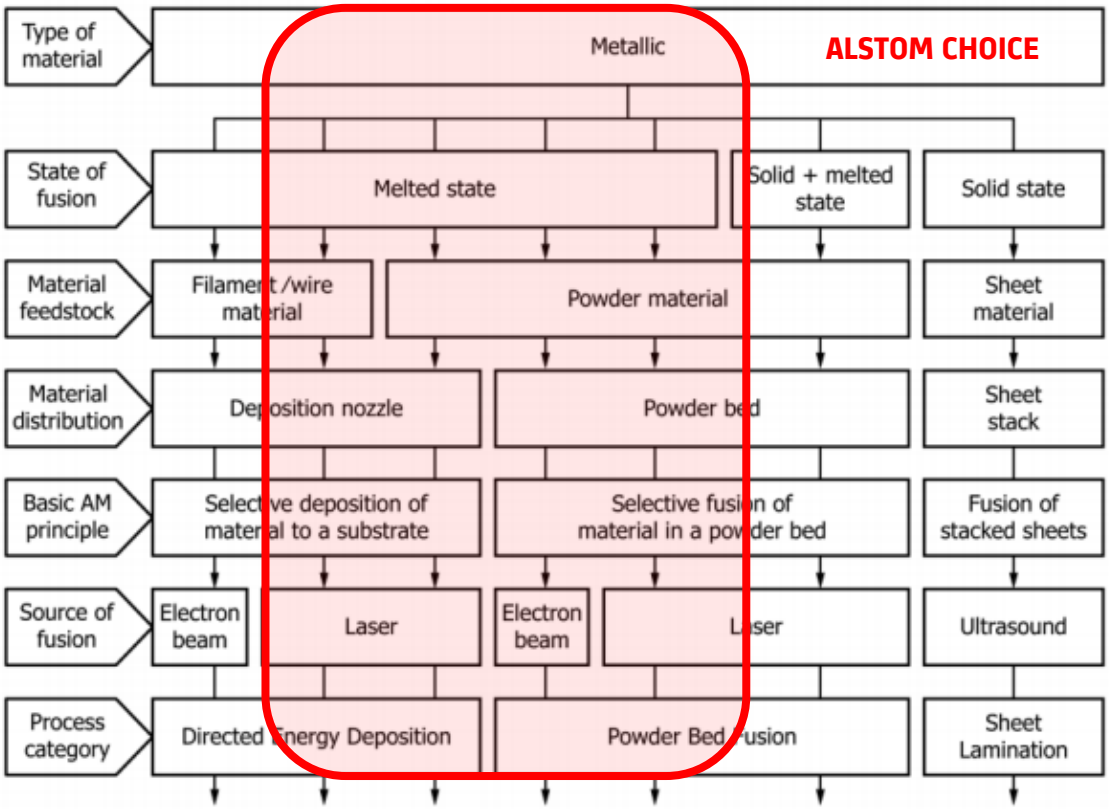

FIG. A1.2 Overview of single-step AM processing principles for metallic materials

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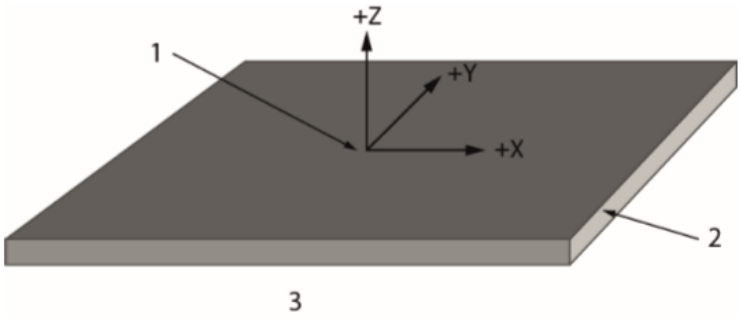
5.2. APPENDIX 2: SAMPLE DEFINITION (ISO/ASTM 52921)

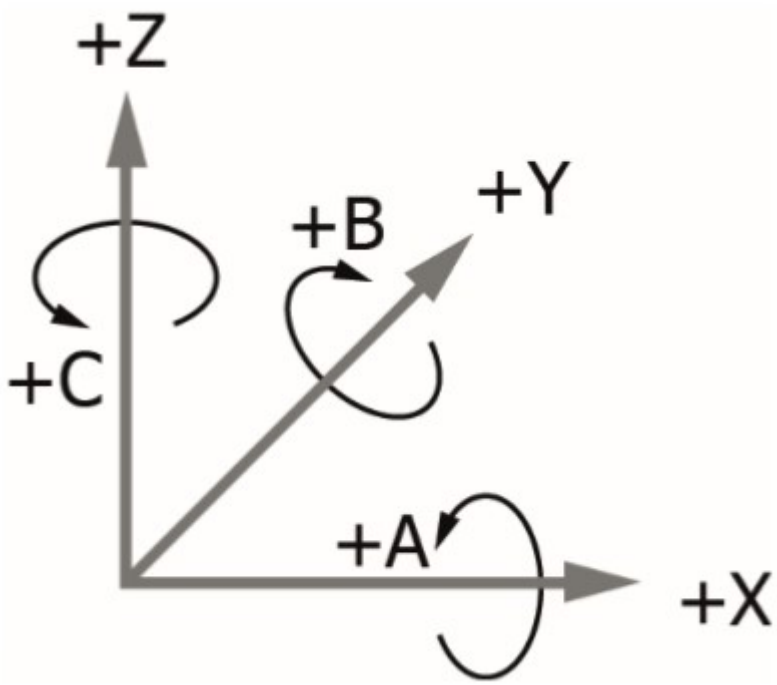
5.2.1 CARTESIAN COORDINATE SYSTEM



Key

1 Build origin (0,0,0)
2 Build platform
3 Fron of machine

5.2.2 RIGHT HAND RULE FOR POSITIVE ROTATIONS



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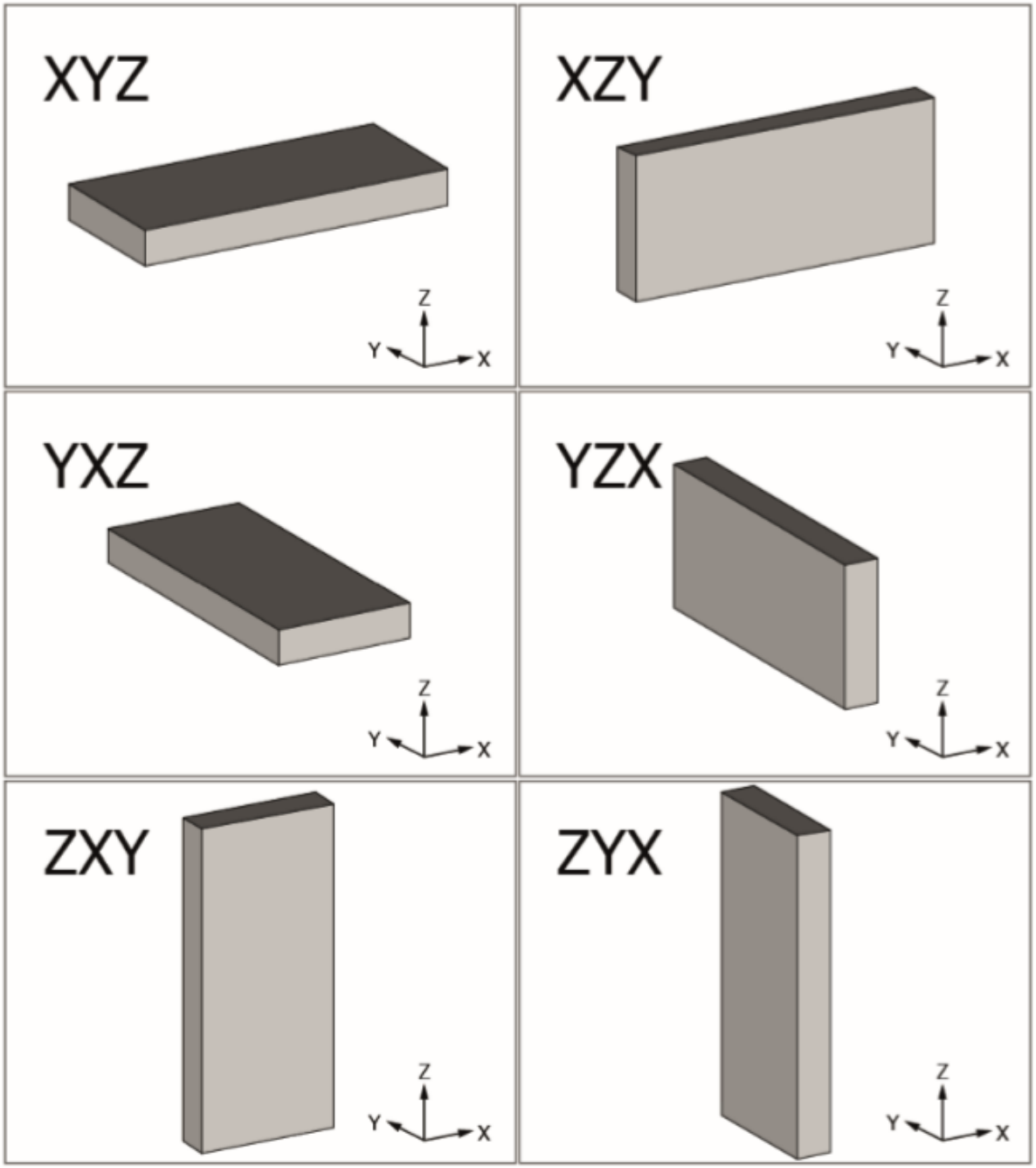
5.2.3 ORTHOGONAL ORIENTATION NOTATION



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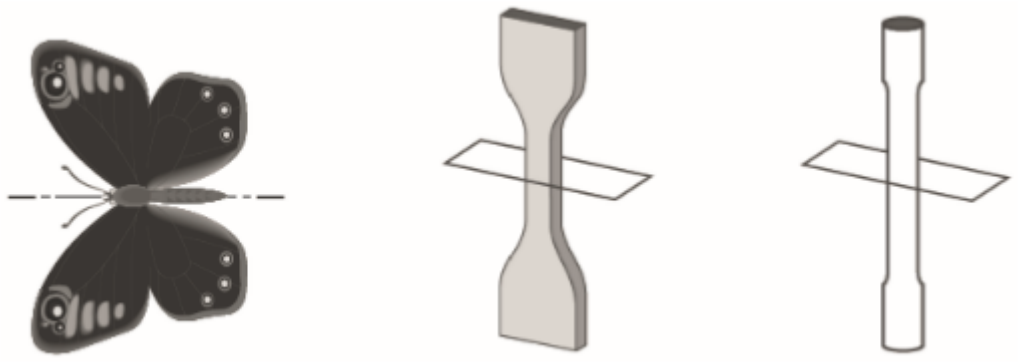
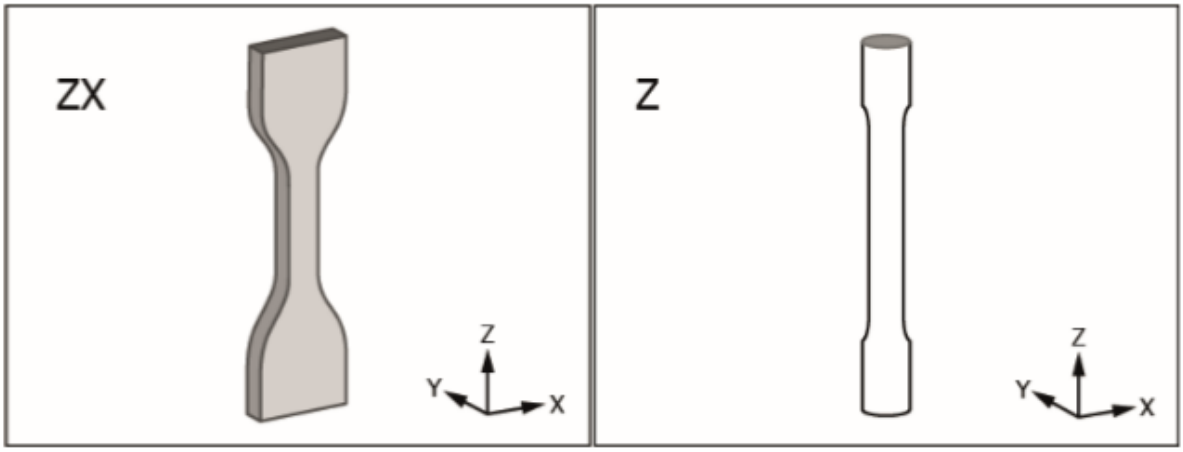
5.2.3.1 BILATERAL SYMMETRY



Examples

5.2.3.2 ABBREVIATION OF ORTHOGONAL ORIENTATION NOTATION



Examples

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